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EVALUATION OF CO_2 STORAGE POTENTIAL FOCUSED ON CO_2 SEALING EFFICIENCY OF THE SEAL LAYER AT A FEASIBILITY STUDY SITE

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ABSTRACT

This paper describes our evaluation of CO_2 storage potential, with a focus on CO_2 sealing efficiency, through numerical analysis using TOUGH2/ECO2N applied to a feasibility study site (which we call "Site D"). To create an axisymmetric model, we simplified the geological situations at the injection point at Site D, and using this model, we examined the relationships between integrity of the seal layer and storage volumes of CO_2. We chose some parameters to carry out a sensitivity analysis for understanding the uncertainty included in the analysis. The sensitivity analysis revealed that permeability, capillary pressure, layer thickness, and modeling of the alternating layers will greatly affect our results. Through this numerical analysis focused on sealing efficiency, we estimate the maximum amount of injectable CO_2 in Site D at 1 million tons per well.

INTRODUCTION

This study is a part of the feasibility study project for Zero-emission Coal Gasification Power Generation with CCS, which was funded by the New Energy and Industrial Technology Development Organization of Japan (NEDO).In this study, evaluation of the quantity of CO_2 that can be confined in a storage layer over a long period at a given site is an important consideration. At this feasibility study stage, when sufficient geological survey data have not yet been gathered, it is also important to understand the uncertainty inherent in the numerical-analysis results.

We collected previous geological survey data and created a geological model for the feasibility-study sites. The number of required injection wells and their locations were determined and, using TOUGH2/ECO2N, we simulated CO_2 migration at a single hypothetical site (Site D).

In this paper, we explore Site D storage potential as estimated by the analysis, paying special attention to CO_2 sealing efficiency and the degree of uncertainty in the analysis results, caused by rock properties and other simulation parameters.

MODEL

Geology

The sedimentary basin in Site D mainly consists of sediments from the Neocene to Paleocene periods, with a thickness of 4,000 meter and an area of 1,500 km^2. This sedimentary basin has a vast amount of previous geological survey data. A refraction seismic survey was conducted through 124 survey lines (a total of 4,162 km in length), and four boreholes were drilled during the survey. These areas are located approximately ten kilometers offshore, with the depth of sea water 150 m. The thickness of the massive sandstone layer chosen as the storage reservoir is ~400 m thick, distributed from 1100 to 1500 m below the seabed. The alternating layers of mudstones (predominant) and sandstones are proposed as seal layers, with thickness of ~200 m, distributed from 900 to 1100 m below the seabed.

Numerical Model

A simplified axisymmetric model was created to represent the geological situation at the selected area. Figure 1 shows a schematic of the model geometry. The radius of the model has sufficient length (100 km) to avoid the effect of a side boundary condition on CO_2 migration behavior. Figure 2 shows the numerical axisymmetric model. Table 1 shows the properties of the reservoir and seal layer as a standard case.

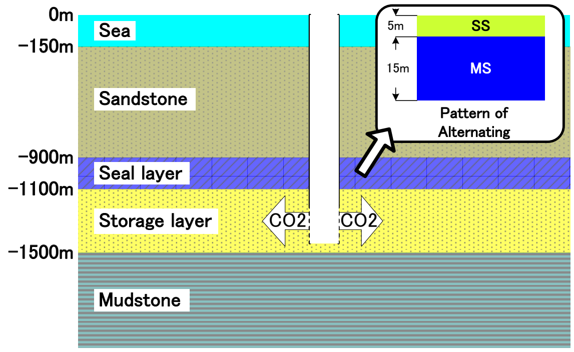


Figure 1. Schematic of model geometry, with simplified geological situation at the injection point.

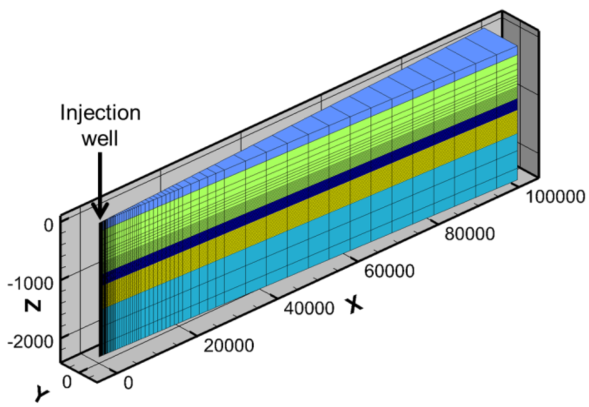


Figure 2. The numerical axisymmetric model.

Conditions of CO_2 Injection

The injection point of CO_2 was selected as through a single vertical well in the middle of the storage layer, at depths from 1250 to 1350 m below the seabed. The rate of CO_2 injection was determined as 1 million tons of CO_2 per year, with a 20-year injection cycle.

SENSITIVITY ANALYSIS

In order to evaluate the quantity/volumes of CO_2 that can be confined in the storage layer over a long period of time, our sensitivity analyses focused on the parameters of the seal layer. The sensitivity of results to (1) the approach to modeling of the alternating layers, (2) permeability, (3) porosity, (4) irreducible water saturation, and (5) capillary pressure of the seal was determined. The ranges of parameters for sensitivity analysis (the maximum and the minimum values) were estimated based on literature data.

Table 1 shows the properties of the standard case; Table 2 shows the variable parameters for the seal layer.

Table 1. Properties of the standard case

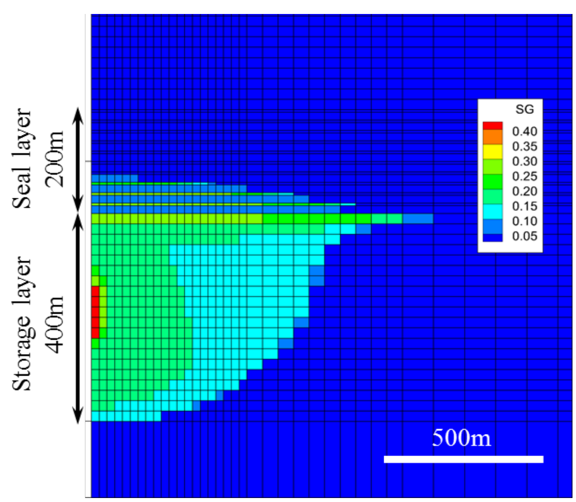
Property	Seal layer		Strage layer
	MS	SS	
Porosity (%)	32	32	30
Permeability (vertical)	0.8	36	3.1
Permeability (horizontal)	0.8	36	18
Relative Permeability			
function	VG1)	VG1)	VG1)
λ	0.4	0.4	0.4
Slr	0.8	0.54	0.6
Sls	0.95	0.95	0.95
Sgr	0.05	0.05	0.05
Capillary Pressure			
function	VG2)	-	-
λ	0.4	-	-
Slr	0.8	-	-
P_0(Pa)	$3x10^5$	-	-
P_{max}(Pa)	$1x10^6$	-	-
Sls	1	-	-

1) Liquid:van Genuchten(1980) ; Gas:Corey(1954)
2) van Genuchten(1980)

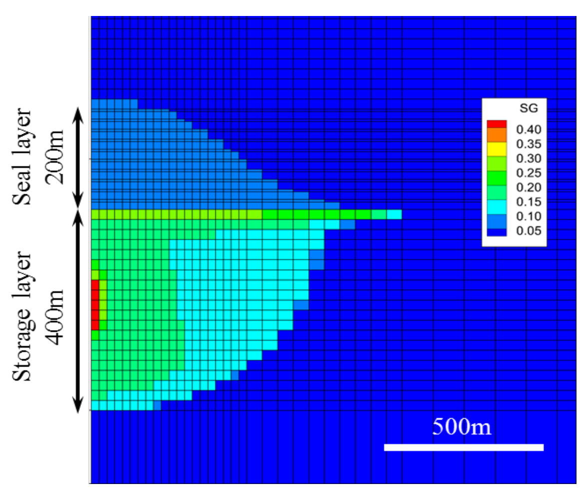
Table 2. Variable parameters of the seal layer.

Item	Standard model	Value of a variable	Case
Modeling	Alternation model	Alternation model	Case1-1
		Equivalent permeability model	Case1-2
Injection rate	1 milion ton-CO2/year	1.5 milion ton-CO2/year	Case2-1
		0.5 milion ton-CO2/year	Case2-2
Permeability	0.8 md	4 md	Case3-1
		0.08 md	Case3-2
Porosity	32%	44%	Case4-1
		20%	Case4-2
Capillary pressure	P_0 = 300 kPa	P_0 = 600 kPa	Case5-1
		P_0 = 30 kPa	Case5-2
	λ = 0.4	λ = 0.8	Case6-1
		λ = 0.2	Case6-2
Irreducible water saturation	Swir = 0.8	Swir = 0.9	Case7-1
		Swir = 0.7	Case7-2
Permeability and Capillary pressure	K = 0.8 md P_0 = 300 kPa	K=4 md, P_0=200kPa	Case8-1
		K=0.08md, P_0=510kPa	Case8-2

Figure 3 shows numerical results that illustrate the difference between Case (a), modeling the alternating mudstones/sandstones, and Case (b), using an equivalent coefficient of permeability. In the case of the alternating layer model, the CO_2 migration front is in the 4th alternate layer, 80 m above the bottom of the seal layer. In the case of the equivalent permeability model, the CO_2 migration front extends just past the top of the seal layer. These results show that dissipation of CO_2 pressure through the sandstone parts of the seal layer influences CO_2 migration. Table 3 shows the results of sensitivity analysis using the alternating-layer model. If one parameter is changed, the difference in the CO_2 migration front is from 40 to 60 m, in many cases. But changes in two parameters show higher sensitivity with respect to CO_2 migration: these are capillary pressure (p_0, λ) and injection rate. Porosity is not sensitive with respect to CO_2 migration through the seal layer.



(a) Alternating layer model



(b) Equivalent permeability model

Figure 3. Simulated CO_2 saturations at t=400years.

Table 3. The results of sensitivity.

Item	Case	CO2 Front Position[1] (m)	Difference (m)	Sensitivity
Modeling	Case1-1	80	>120	High
	Case1-2	>200		
Injection rate	Case2-1	100	60	Medium
	Case2-2	40		
Permeability	Case3-1	80	40	Low
	Case3-2	40		
Porosity	Case4-1	80	0	very Low
	Case4-2	80		
Capillary pressure	Case5-1	40	>160	High
	Case5-2	>200		
	Case6-1	100	60	Medium
	Case6-2	40		
Irreducible water saturation	Case7-1	40	40	Low
	Case7-2	80		
Permeability and Capillary pressure	Case8-1	80	40	Low
	Case8-2	40		

1) From bottom of seal layer

CONCLUSION

Based on the sensitivity analysis, there are no cases in which CO_2 leaks through the seal layer, except when there are unrealistic parameter conditions. Consequently, even allowing for a degree of uncertainty (in rock properties), we believe that an injection rate of 1 million t-CO_2 is feasible at Site D. However, further investigation is required for the situation of alternating seal layers and the characteristics of the capillary pressure in the seal layer.

In this project at Site D, two different types of injection quantities are considered:

(1) Commercial project level of 31 million tons-CO_2 in total (1.54 million tons-CO_2 per year, 20-year injection cycle)

(2) Large-scale CO_2 storage, assumed to be 200 million tons in total (10 million tons-CO_2 per year, 20-year injection cycle).

The number of required injection wells is two for the commercial project and ten for large-scale CO_2 storage. We think that further research is in order, to reproduce more detailed geological conditions within a numerical model.

ACKNOWLEDGMENT

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